THE IN-PLACE POLLUTANTS PROGRAM

VOLUME V, PART A

A SYNTHESIS OF BENTHIC INVERTEBRATE STUDIES

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A SYNTHESIS OF BENTHIC INVERTEBRATE STUDIES

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PREFACE

The In-Place Pollutants Program addresses the impact of contaminants in sediment on overlying water quality and aquatic biota with the aim of developing strategies for the management of contaminated sediments.

This report, Volume V, describes the Benthic Invertebrate Studies and discusses the findings. The report is divided into two separate parts - Part A provides a synthesis and Part B provides the results and a detailed discussion of the findings.

Companion volumes provide the following:

Volume I - A Program Overview (March 1987)

Volume II - Background and Theoretical Concepts (March 1987)

Volume III - Phase I Studies (Oct. 1987)

Volume IV - Phase I Data Summary (Oct. 1987)

Subsequent phases of the In-Place Pollutants Program will be reported in other volumes of this series.

The In-Place Pollutants Program of the Ministry of the Environment is supported in part by funds received from Environment Canada under terms of the Canada-Ontario Agreement (COA) on Great Lakes Water Quality. Activities are co-ordinated with those of the Federal government under the guidance of the COA Contaminated Sediments Committee.

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Integrated Explorations carried out the benthic surveys (1985) and staff of the MOE Laboratory Services Branch performed the chemical analyses on water and sediment samples.

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TABLE OF CONTENTS

SUMMARY AND CONCLUSIONS

This report provides a synthesis of the studies associated with the second phase of the In-Place Pollutants Program which focused on the impacts of contaminants in sediment on the structure and function of the benthic communities in ten locations of the Great Lakes in 1985. The study examines whether any significant toxic effects from contaminants in sediment are reflected in the composition and density of the benthic community. A synthesis of the study is provided in this report (Part A) while detailed information is provided in Part B.

The ten locations studied showed variations in sediment type and chemistry and in composition of the benthic communities. In most of the areas with "clean" sediments (based on guidelines for Open-Water Disposal - Persaud and Wilkins, 1976), the benthic communities were reflective of specific physical environmental factors, especially substrate type. Most of the areas with elevated levels of contaminants in the sediment also had high levels of organic matter. In these areas the benthic communities were reduced to "pollution" tolerant species such as the oligochaetes. The term pollution is used in the traditional sense of benthic ecology and refers to high organic matter (the breakdown of which results in a lowering of dissolved oxygen levels) rather than to chemical contaminants.

Many organisms cannot survive in sediment with low dissolved oxygen and are eliminated. The effect of low dissolved oxygen is readily discernible in that the benthic community is reduced to specific species known to be tolerant of such conditions. In many instances, there were indications that in addition to stress induced by low dissolved oxygen, chemical contaminants in the sediment were also exerting stress on the community.

The results suggest that species that are tolerant of low dissolved oxygen can tolerate high levels of chemical contaminants in sediment. Various theories have been advanced to explain this phenomenon and some of these are addressed in the discussion section of this report.

Several important points emerge from this study. Natural environmental factors, especially substrate type, are significant in determining the composition of benthic communities; the most discernible chemically-related influence on the communities is low dissolved oxygen levels in areas with high organic matter content. Evidence, in several areas, points to additional stress from chemical contaminants in the sediments, but no conclusive findings regarding the specific contaminants responsible for this have been obtained. This is an inherent problem with benthic enumeration studies which can only be resolved through appropriate experimental studies and/or careful evaluation of several years of benthic data.

Notwithstanding the evidence that chemical contaminants in sediment may be exerting stress on the benthic population in areas with low dissolved oxygen, it appears that where suitable substrate exists, improvements in benthic community composition (e.g. to a community with a greater number of species) will first require improvements in the dissolved oxygen levels of the benthic habitat. This in turn will require reductions in the input of organic matter and nutrients to the system. Anthropogenic source reductions in organic matter may also provide the added benefit of contaminant reduction since many chemical contaminants are associated with the organic fraction of effluents and sediment.

As noted in the discussion section of this report many case studies (e.g., Creese 1987, Beak 1988, Griffiths 1988) show that source control can effect significant improvements in benthic community structure. Remedial action other than source control may be unwarranted from the perspective of improvements in benthic community structure in contaminated areas. Any remedial action for sediments should be carefully considered as it may destabilize sediment-bound contaminants and aggravate the problem.

The ability of certain benthic organisms to survive in areas with elevated levels of contaminants in sediment raises concerns with regard to the uptake of these contaminants by the organisms. The uptake of contaminants by benthic organisms has been demonstrated in an earlier (Volume III) study of the In-Place Pollutants Program (Persaud et al., 1987). The accumulated contaminants present the potential for food chain transfer to higher trophic levels that feed on the benthic organisms themselves. The significance of contaminant residues in benthic tissue must be addressed.

The findings of this study have several implications related to the direction of future studies and decision - making with regards to sediment management in areas of concern. Key issues are highlighted in the following recommendations.

RECOMMENDATION 1

Data from single benthic enumeration studies should not be used as the sole basis for making sediment management decisions in areas of concern unless there is a complete absence of benthic life, and this condition can be unequivocally attributed to a specific toxic event or substance.

RATIONALE

Because of the variety of physical, chemical and biological factors that can potentially influence benthic community composition, reliance cannot be placed on benthic community information alone to assess sediment quality. Recent MOE studies show that while benthic community data cannot unequivocally show cause-effect relationships beyond the "classical" low dissolved oxygen effects or inappropriate substrate characteristics, they are suggestive of detrimental effects caused by chemical contaminants. Additional evidence must also be sought through proper laboratory bioassessments.

RECOMMENDATION 2

Impacts of contaminants in sediments on benthic organisms should be determined through bioassays on sediments as well as traditional ecological field studies.

RATIONALE

The need for and the degree of source control should be established based on the characteristics and impact of the effluent on both the water column and sediments. In this regard effluent limits should incorporate: (1) protection of sediments since a significant portion of contaminants in effluents may eventually end up in bottom sediments. Where the dispersion characteristics of the specific receiving environment are such that material will accumulate in sediments to undesirable levels,

adequate reductions in the effluent should be made. This is especially warranted for oxygen-demanding wastes and contaminants that accumulate in benthic tissue; (2) protection of receiving water since contaminants in the water column can impact the benthic community. Benthic bioassays will be required to determine the appropriate discharge levels to ensure that water column - related impacts do not occur.

RECOMMENDATION 3

Sediment management in areas with stressed or contaminated benthic communities should focus on source control as the first step in remedial action.

RATIONALE

The literature shows that severely stressed benthic communities can rebound within relatively short periods once the source of pollution has been eliminated or substantially reduced. Recent MOE studies show that, where historical information exists, there have been improvements in the benthic community which are indicative of reduced stress. Some of the improvements have been attributed to better effluent quality. The merits of source control are also strengthened by the fact that the sediments in the vicinity of effluent discharge points contain some of the more severely stressed benthic communities. It has also been demonstrated that significant bioaccumulation of many contaminants found at very low levels in sediment can occur in the vicinity of effluent discharges, suggesting that contaminants are taken up directly from the aqueous phase.

RECOMMENDATION 4

Benthic studies should be utilized in monitoring changes resulting from pollution abatement or sediment clean-up.

RATIONALE

The success of pollution abatement measures cannot be fully judged without regard for the benthic community since the eventual goal of any remedial plan should be the protection of all species capable of inhabiting a particular area. When conducted properly, benthic surveys provide good synoptic overviews of trends in the "health" of the community. However, because of the large numbers of variables that can influence the benthos, such surveys done cannot be used to determine the specific agents responsible for changes in a community. Instead benthic surveys should be used in conjunction with other information (e.g., bioassays, sediment and effluent chemistry) to evaluate changes resulting from pollution abatement.

RECOMMENDATION 5

Emphasis must be placed on setting guidelines for acceptable residue levels for contaminants in benthic tissue. Studies leading to such guidelines should determine whether uptake by organisms presents a potential problem both to the organisms themselves and their predators.

Determination should be made, through appropriate laboratory studies, of the level of contaminants in sediments that would be required to ensure that the guidelines for residue levels in biota are not exceeded.

RATIONALE

The In-Place Pollutants Program studies show that some species of benthic invertebrates can survive in areas with high levels of sediment contamination. These organisms have the potential to accumulate contaminants which could subsequently be transferred up the food chain. The significance of contaminant residues in

organisms can only be partially determined on the basis of current knowledge. In many areas, contaminants in biota are a potential concern and will continue to be until their significance can be established. The issue of contaminants in sediment and/or benthic tissue may be a major determinant in remedial action required in many contaminated waterways in Ontario including IJC Areas of Concern.

1.0 BACKGROUND AND PURPOSE OF THE STUDY

The major objective of the Phase II studies of the In-Place Pollutants Program was to examine the feasibility of using information based on the distribution and abundance of benthic organisms to determine whether contaminated sediments are exerting a toxic influence on the biota.

Traditionally, benthic enumeration studies have been carried out in a "water-quality" context, especially in relation to determining the "trophic" status of an area within a water body. In this regard "pollution" was tied to the degree of organic enrichment of the sediment. Areas where sediments were elevated in organic matter content, often through natural processes, were termed "eutrophic" while areas with organic matter comprising a significant portion of the sediment makeup (usually due to anthropogenic changes) were referred to as being "organically polluted".

The terms "eutrophic" and "organically polluted" (or polluted) have remained standard terminology in characterizing areas based on benthic community composition. Organically polluted areas usually experience depleted oxygen levels in the bottom waters as a result of the decomposition of the organic matter. Oxygen levels in these areas can reach such low levels that many species of benthic organisms cannot survive and the community is reduced to only those species that can tolerate low dissolved oxygen levels. Such communities are comprised mainly of a group called the tubificid oligochaetes, and to a lesser extent, the chironomids.

In a "healthy" benthic community, the numbers of organisms are normally determined by interspecific competition for available food resources and by predators. Such a community is comprised of many species present in "low" densities. In an organically polluted area, the tolerant species that are able to survive find an abundant food source in the organic (nutrient-rich) sediment and because of the absence of competition from other groups of organisms, their numbers increase significantly compared to the numbers in unpolluted areas.

The anticipated high numbers of pollution tolerant organisms in polluted areas may be reduced if high levels of chemical contaminants are present. This is often an indication of possible toxic influence from the contaminants in sediments.

In contrast to organically polluted areas, a "eutrophic" area is normally comprised of a more balanced community with more species in lower densities.

One of the drawbacks to benthic enumeration studies is that they do not provide conclusive evidence of cause-effect relationships. This stems from the fact that there are a large number of factors in the natural environment that could potentially affect a benthic community. Factors such as suitability of substrate type and dissolved oxygen have been studied extensively so that their influence on the community is well known. The influence of other factors such as chemical contaminants are less clearly defined, and at present, apparent effects are more suggestive than conclusive.

In many situations deductions regarding a benthic community in an area with elevated levels of contaminants are made through comparisons with another area that has few apparent differences except the level of contamination. This practice, however, is not without problems.

The sediment ecosystem is a complex biogeochemical system with various physico-chemical regulatory mechanisms that influence an organism's ability to survive at a given location. In general, organisms tend to become acclimated to their particular micro-habitat, the characteristics (substrate-type, current patterns, temperature, pH, Eh, depth of water, biological composition, etc.) of which may be unique in many respects. It is often difficult to define a "typical ecosystem" that can be used as a standard against which other ecosystems can be evaluated due to the problems inherent in finding two areas with only a single difference (Sheehan, 1984).

In the past, the most useful application of benthic enumeration studies has been in determining trends in community composition over time within a defined area. Since a substantial database on the interactions of benthic communities and environmental parameters now exists, future studies must focus on fluctuations in these communities as influenced by anthropogenic changes. In particular, studies now need to focus on determining levels of contaminants that can be sustained without impairment of the aquatic biological community. The complex, and often unpredictable behaviour of many of the contaminants presently occurring in sediments (for example, most of the metals) has identified a critical need for in-situ assessment of aquatic biological systems. While laboratory studies can effectively determine simple cause-effect relationships, these may not necessarily hold true when applied to field situations, where a large number of environmental factors can alter these relationships. With good baseline data and well-designed trend studies, benthic community information will be extremely valuable in monitoring changes in response to pollution abatement or sediment remediation measures.

The purpose of the Phase II In-Place Pollutants Studies was to critically evaluate the use of benthic enumeration information in the assessment of contaminated sediments and, taking cognizance of the concerns outlined above, to develop strategies to enhance the use of benthic information in sediment assessment. From this perspective, benthic enumeration studies were carried out in various locations of the Great Lakes. The intent was to observe the benthic community composition in areas with different sediment type, chemistry and environmental conditions. The following sections describe the methods employed and the results of the studies. Detailed information on the findings and data tables are provided in Part B of this report.

2.0 METHODS

During the 1985 field season, 110 stations from 10 locations in the Great Lakes were sampled. The locations and number of stations are provided in Table 2.1. Station location maps are provided in Section 3 of this report.

2.1 Field Sampling

2.1.1 Sediment

Sediment collection was carried out using a 9" x 9" Ponar grab sampler. pH and Eh readings were taken for the top 3 cm of each sediment sample in the field with a Corning pH and Eh meter.

The sediment samples were kept at 4°C, returned to MOE laboratories in Rexdale and submitted for bulk chemical analyses.

2.1.2 Water

Water samples were collected from 1 m off the bottom using a Van Dorn water sampler. Samples were placed in appropriate jars, preserved depending on analytical requirements (OMOE, 1983) and then transported to MOE laboratories in Rexdale for analysis.

Dissolved oxygen (D.O.) measurements were taken at each station using a Corning D.O. meter.

2.1.3 Benthic Invertebrates

Three replicate sediment samples were taken at each station, each of which was a composite of 5 Ponar grab samples. Samples were field washed using a U.S. #30 mesh (approximately 600 µm) seive and the residue remaining was stored in 5-10% buffered formalin and transported to the laboratory for identification.

TABLE 2.1: Study Locations and Number of Stations

STUDY LOCATIONS	NO. OF STATIONS
Lake Ontario	
Toronto Waterfront Toronto Harbour Toronto Outer Harbour Toronto Outer Harbour & Eastern Headland Humber Bay	27
Oakville Harbour	9
Port Weller Harbour	6
Bay of Quinte	10
Lake Huron	
Midland Bay	10
Penetang Harbour	10
St. Marys River	10
Detroit River	10
Niagara River	8
St. Clair River	10

2.2 Laboratory Procedures

2.2.1 Bulk Sediment Chemistry

Sediment samples were submitted to the MOE Rexdale laboratory for bulk chemical analyses on the entire sediment matrix. The bulk chemical analyses included loss on ignition, total Kjeldahl nitrogen, total organic carbon, total phosphorus, chromium, iron, manganese, mercury, cadmium, zinc, copper, lead, arsenic, solvent extractables (oil and grease), PCBs, pesticides and grain size.

Analyses were carried out in accordance with the MOE procedures (OMOE, 1983) and all parameters were reported on a dry weight basis. Analytical results are provided in Part B of this report.

2.2.2 Water Chemistry

Analyses were performed on unfiltered water samples for nutrients, pH, major ions, metals, pesticides and chlorinated aromatics following the procedures described in OMOE (1983).

2.2.3 Benthic Invertebrates

All replicate samples were sorted, the specimens identified to ordinal level and enumerated. Large samples were subsampled where necessary. Subsampling was done by dividing the washed sample into a number of sections on a grid, from which subsamples were chosen at random. All specimens removed from the samples were stored in 80% ethanol.

The sample closest to the mean for the three replicates was chosen for detailed identification of the organisms present. The remaining two replicates were used to estimate live-weight (g/m^2 per taxa) biomass.

Identifications were made using the most recent taxonomic literature available (a list is provided in Part B) and the species lists reflect the most recent systematic treatments for each order.

2.3 Data Evaluation

The benthic community was analyzed on the basis of species composition as well as the functional feeding groups present. Community structure analysis relied primarily on differences in density and diversity of the known tolerant, facultative and intolerant species. Analysis of functional feeding groups also compared the density and diversity of the species present, but based on their trophic relationships. The groups considered are listed in Part B of this report.

In both the community structure analysis and the functional feeding group analysis, differences in species composition between stations were first evaluated on the basis of environmental factors known to affect benthic community structure. Any unaccountable differences were considered in relation to contaminant levels in the sediment.

Analysis of community structure was performed using equations derived from information theory as well as species presence/absence data. Functional feeding group data were analyzed on the basis of presence/absence data.

The following section summarizes the main findings from each of the locations studied.

3.0 RESULTS

3.1 Lake Ontario

3.1.1 Toronto Waterfront

Multivariate statistical analyses of benthic community structure as well as environmental factors and sediment contaminant levels were performed on data from the Toronto Waterfront (Dilke, 1987). Data from that analysis corroborate the findings of this report.

3.1.1(a) Toronto Harbour

The sampling stations within Toronto Harbour were distributed to provide coverage of the northshore of the harbour, the central portions of the harbour and the southshore along the Toronto Islands. Station locations are provided in Figure 3.1.

Benthic survey results indicate that distribution and density of the major groupings of the benthic fauna in the harbour parallels these geographic divisions. The first zone (Stations 1346, 1360 and 1379 i.e., the northshore) consisted of organically enriched sediments with high contaminant levels. These ranged from a low at Station 1379 (TOC = 26 mg/g and relatively low contaminant levels) to a high at Station 1346 (TOC = 50 mg/g, 11 of the 13 parameters measured exceeded MOE guidelines). At all three stations, the organisms feeding on fine sediment in general, and the oligochaetes in particular, formed the major segment of the community (not less than 99%). The *Tubifex tubifex* - *Limnodrilus* spp. community typical of organically enriched conditions dominated at all three stations as a result of the high organic levels. Density and biomass of oligochaetes were high at all three stations (as was the proportion of immature worms) despite the elevated contaminant levels and were in fact highest at Station 1360 where contaminant levels were also the highest. Other organisms, present in low densities relative to the oligochaetes, were of only minor importance. Contaminant levels appear to have had little effect on the rather restricted existing

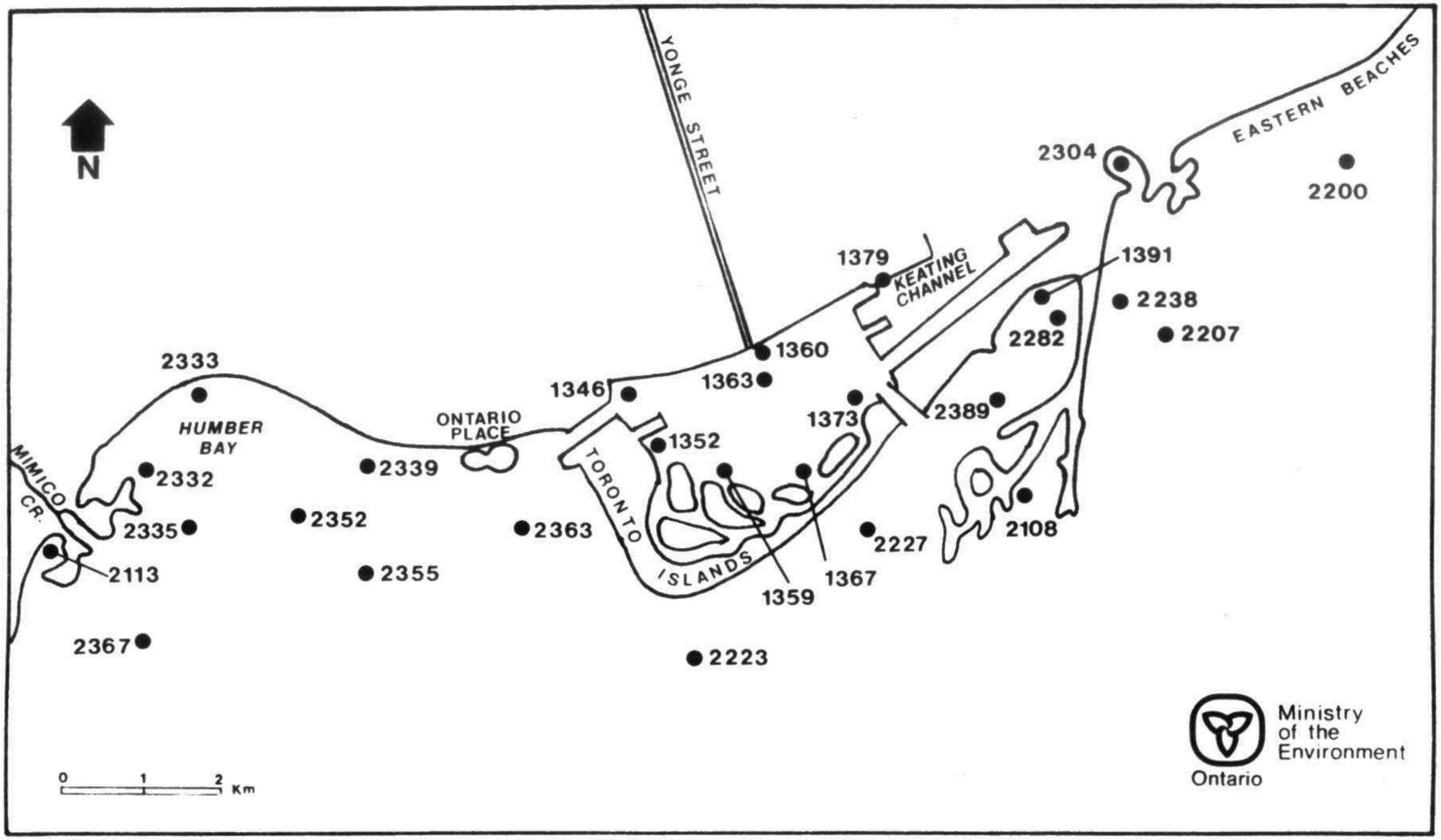

FIGURE 3.1: TORONTO WATERFRONT, LOCATION OF SAMPLING STATIONS.

benthic fauna. This does not suggest, however, that the contaminant levels did not serve to limit colonization of these areas by other organisms.

The second zone (the central harbour) was represented by Station 1363 and was considered a transitional zone between the heavily organically polluted northshore and the littoral areas of the southshore. One of the most heavily polluted areas during the 1969 survey by Brinkhurst (1970), this area appears to have undergone some improvement since then. Specifically, this improvement was reflected in the increased diversity among functional feeding groups and a decreased dominance of the benthic fauna by oligochaetes. Suspended particle load and organic content of the overlying water were high, and this station appeared to be situated in a major depositional area of the harbour. Sediments were predominantly silts (64%) but organic content was low, indicating that much of the material that had accumulated may have originated in shallower areas. The benthic fauna as a result was almost exclusively composed of fine-sediment particle feeders, T. tubifex and Limnodrilus spp., though sediment surface feeders such as the clam Pisidium casertanum also formed a significant part of the community.

The four stations located in shallow areas along the shoreline of the Toronto Islands formed the third zone. All four (Stations 1352, 1359, 1373, and 1367) were characterized by sandy substrates with very low organic matter content and contaminant levels. The fauna was typical of littoral areas, being comprised of high densities of epibenthic species commonly associated with accumulations of coarse detritus (the amphipods Gammarus spp. and various chironomid species). Density of epibenthic grazers ranged from a low of 29% of total density at Station 1359 (mainly Endochironommus and Gammarus fasciatus) to a high of 78% of total density at Station 1367, and their density appeared to be affected by sand content, highest at Station 1373, and the presence of macrophytes (high at Station 1367). The presence of macrophytes is usually associated with a pronounced difference in the species composition, favouring those species that feed on microorganisms and seston occurring on macrophytes.

Oligochaetes formed only a minor part of the fauna even at those stations where organic content was highest, though the species composition had changed little from the other areas of the harbour.

While the composition of the benthic communities in areas along the northshore indicates these areas have been heavily impacted by organic matter, the benthic communities of the littoral areas of the southshore appeared largely unaffected by organic contamination. Rather, water depth, the occurrence of macrophytes and the presence of coarse detritus appeared to be the major factors affecting benthic community structure.

3.1.1(b) Toronto Outer Harbour and Eastern Headland

Three broad regions, as defined by benthic community structure were also delineated in the Outer Harbour/Eastern Headland area. The first was an area of organic deposition which occurred in the protected bays and shallows along the Outer Harbour and Eastern Headland (Stations 1389, 1391, 2282, 2108, and 2034). These bays were characterized by accumulations of organic matter as well as various contaminants, though most were not seriously contaminated with the exception of Ashbridges Bay. High contaminant levels here may have played a role in limiting the faunal density as compared to other stations in this area. In general, benthic community structure was typical of organically enriched areas.

All of the stations were located in depositional areas of primarily silt and clay and contained moderately high amounts of organic matter. Three of these were in the Outer Harbour (1389, 1391, 2282) where substrate type ranged from mainly sand (1391) to silt and clay (1389) (10 parameters exceeded MOE guidelines with PCB's well above). Contaminant levels were lowest at 1391 (only one exceeded MOE guidelines) where sediments were mainly sand.

Oligochaetes dominated at these 3 stations, though diversity was moderately high. In general oligochaetes comprised a greater proportion of the fauna in the more organically enriched areas (1389) and were less important at the others. The sandier areas supported faunas rich in epibenthic grazers such as Gammarus fasciatus (1391, 10% of the fauna) and the chironomids (C. plumosus). The latter, though numerically fewer, formed most of the biomass at Station 2282 (78%). It appears are that organic matter is a problem in the Outer Harbour.

Only one station, 2108, was located in a cell of the eastern headland. Organic content was low (primarily sand substrate) as were most contaminants, with the exception of PCBs and solvent extractables. The overall benthic density was lower than at the previous stations and, though oligochaetes were still the dominant group, benthic diversity was higher.

The last station considered in this group was 2034, located in Ashbridges Bay. This station yielded the highest sediment organic content of any of the stations outside the harbour (TOC = 41 mg/g; LOI = 8.5%). Contaminant levels were also very high and in some cases exceeded MOE guidelines by nearly 10 times (e.g., solvent extractables and Cu) or more (PCBs were 18 times more than the guidelines). Despite these increased levels, a sizeable oligochaete community did exist though only the most pollution tolerant forms were present. Density however was considerably lower than other areas of the Toronto Waterfront with similarly high organic content. Since elevated organic levels commonly result in large increases in oligochaete density, presumably other factors were acting to limit the density. Both a high rate of sedimentation or significantly elevated levels of contaminants could result in reduced density of oligochaetes.

The second region (Stations 2238, 2200, and 2207) was one of an erosional environment, located offshore of the Eastern Waterfront and Eastern Headland and these stations were characterized by

sandy substrates supporting low densities of organisms. Contaminant levels and organic matter levels were low and the major factors affecting the benthos appeared to be current and substrate type.

The deeper, offshore areas comprised the third region. Sediments were low in organic content and the fauna at these Stations (2223 and 2227) was eutrophic-mesotrophic in character, and contained a number of organisms commonly found in the profundal regions of Lake Ontario, such as Monodiamesa depectinata, Potthastia longimana, Pontoporeia hoyi, and Stylodrilus heringianus. Depth and substrate appeared to be the major determining factors. Contaminant levels were generally low and had no apparent effect on the benthic community. Organic matter was again the single major factor and oligochaetes [44% of the fauna at Station 2223 (mainly Stylodrilus heringianus)] and the pelecypods were the most important species.

Thus a progression in sediment quality from nearshore, organically enriched areas, to deeper, relatively less contaminated open-water areas was mirrored by changes in the benthic community. These changes were mainly a reduction in the density of pollution tolerant forms and an increased diversity of mesotrophic and oligotrophic species.

3.1.1(c) Humber Bay

A total of 4 zones were defined in Humber Bay according to the composition of the respective benthic communities. The first was a shallow- water zone characterized by fine sediments of high organic content. The benthic community was typical of eutrophic littoral areas and comprised mainly of fine particle feeders (chironomids and oligochaetes). Where contaminant levels were low, faunal diversity (Station 2113) and density were high. Where contaminant levels were high, faunal density and diversity were reduced (Station 2332). This zone is restricted to the protected bays and shoreline areas.

Both stations were located at or near the lakefill either in the enlargements (2113) or near the sewage treatment plant discharge (2332). Organic content of the sand-silt sediments at Station 2113 was moderately high and supported a sizeable community of oligochaetes (97% of the fauna) which was considerably larger and more diverse than at Station 2332. The bay appears to act as a settling basin for sediment. Though Station 2332 did have significantly higher contaminant levels, these were lower than the levels at Station 2335 (the highest levels in this part of the waterfront) which yielded much larger benthic populations. The reasons for this disparity are unclear since the physical characteristics of the sediments were very similar.

The second zone was an erosional area along the open shoreline of the bay, which as a result of wave or current action appeared to retain little organic matter. As a consequence, these areas (Stations 2333 and 2339) were low in sediment organic content, and density and biomass of the benthos was lower. The sandy substrate, low in organic matter, bore little evidence of contaminants.

The third zone, located further offshore, lay in an area of deeper water. The sediments (fine particles) were likely carried as outwash from the Humber River and Mimico Creek, and as washdown from shallower, shoreline areas. This area of silty sediments, high in organic content (Station 2335), was characterized by high densities of typically eutrophic species (oligochaetes).

The single station representing this zone (2335) yielded mainly silty sediments high in clay and rich in organic matter. Despite sediment contaminant levels that were the highest of any of the stations in Humber Bay for almost all the parameters measured, this area supported a sizeable benthic community. All of the organisms present were sediment fine particle feeders comprised mainly of the *Tubifex tubifex* - *Limnodrilus* spp. community common to organically polluted areas.

The last zone was the deeper, mesotrophic area furthest out into Lake Ontario (Stations 2352, 2355, 2363, and 2367). Though characterized by faunal elements typical of the deep, oligotrophic areas of Lake Ontario, they did contain some characteristically eutrophic species as well. Contaminant levels were generally low though they did vary with sediment organic levels. No discernable effect on the fauna could be determined from the community structure.

All stations yielded a benthic community consisting of a mix of eutrophic species and deepwater, characteristically mesotrophic to oligotrophic species (Pontoporeia hoyi and Stylodrilus heringianus). This mix was more pronounced at Stations 2352 and 2355 than at Stations 2363 and 2367. The latter were more eutrophic in character and generally were indicative of shallower, warmer water. A higher sediment organic content at Stations 2355 and 2363 was likely responsible for the increased density at these stations. The concomitant increase in sediment contaminant levels (to only moderately above MOE guidelines) had no clearly identifiable effect on the benthic community, with contaminant levels, on the whole, much lower than in the nearshore areas mentioned earlier.

3.1.2 Oakville Harbour

Sediment conditions and hence benthic habitats were more or less homogeneous throughout this study area. Sediments at most stations (Figure 3.2) were predominantly silts and sand with silt content higher at those stations in protected bays (2840 and 2844) and sand content higher at those stations near the mouth of the creek (2847 and 2848).

The benthic communities differed little among all stations with the exception of those located in an erosional environment at the mouth of Oakville Creek (2847 and 2848), where both density and diversity were reduced. Oligochaetes and chironomids were the dominant fauna at all other stations, comprised mainly of the

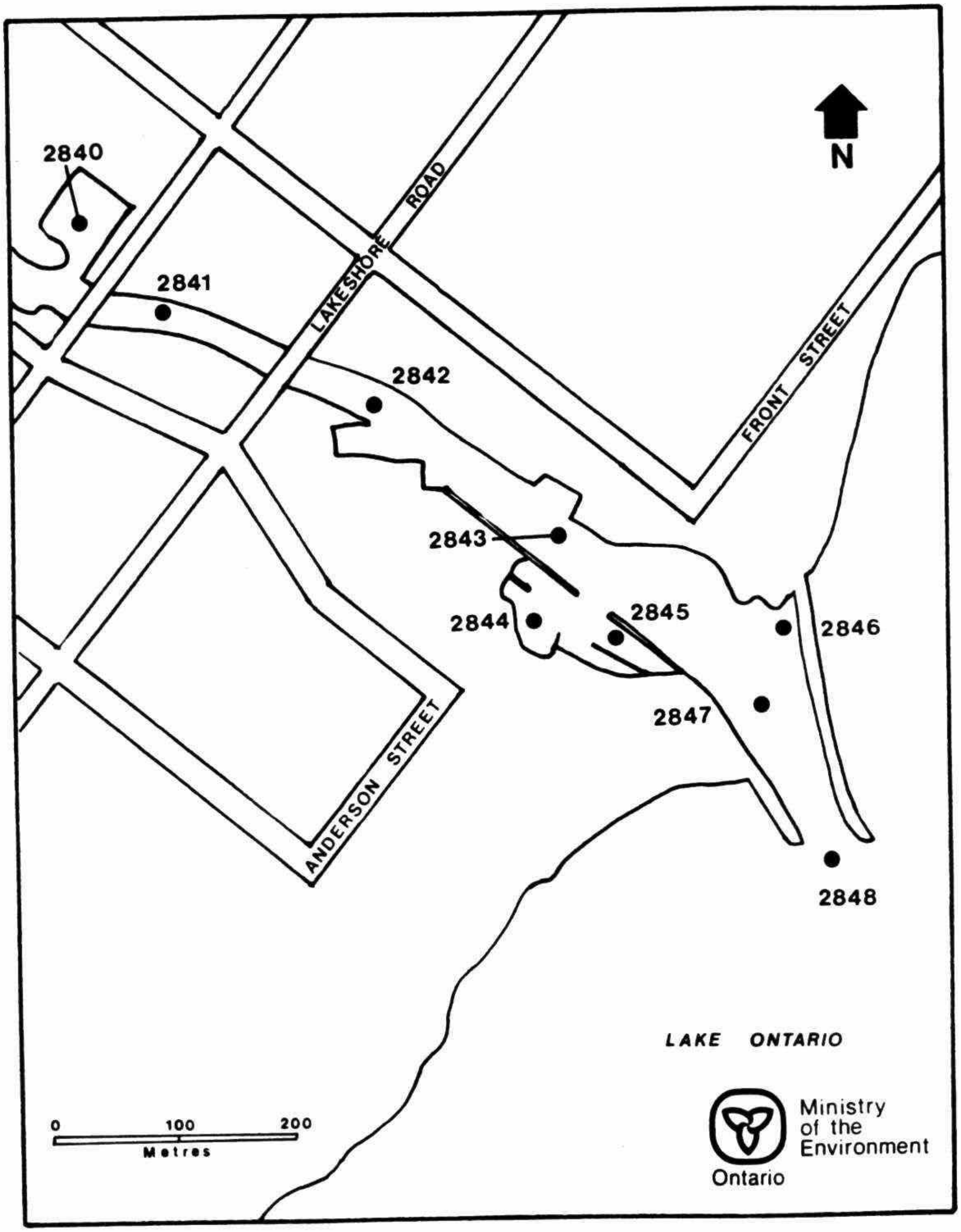

FIGURE 3.2: OAKVILLE HARBOUR, LOCATION OF SAMPLING STATIONS.

Tubifex tubifex - Limnodrilus hoffmeisteri and Chironomus Procladius assemblage typical of organic sediments (organic content was moderately high at these stations; TOC ranged from 10 to 18 mg/g). Stations in the creek itself generally also had some species typical of lotic habitats (Caenis, Ephemera simulans, Hydropsyche, Chimarra) in addition to the above-mentioned species. Lotic species were usually absent in the bays.

Contaminant levels were only slightly above MOE guidelines, though those stations with higher silt content (2840 and 2844) had consistently higher levels. These levels contrasted sharply with those stations at the mouth of the creek (2847, 2848) where contaminant levels were well below MOE guidelines.

Contaminant levels apparently had little effect on the benthic fauna since at those stations where levels were reduced (likely due to a high sand content) the benthic community was also reduced (severely at Station 2848). Even at these stations the basic community composition remained unchanged and was dominated by the oligochaetes-chironomid community noted above. At most, density was reduced as was overall diversity of some of the other benthic species. It is apparent therefore that sediment type and organic content had the major effect on the fauna.

3.1.3 Port Weller Harbour

Of the ten stations projected for Port Weller Harbour (Figure 3.3) samples were only obtained at six stations due to hard substrates at the remaining four stations. Of these six, four stations (2431, 2435, 2438 and 2444) were located in areas of sand substrates (inferred for Station 2438 on the basis of the benthic community) very low in organic content. These areas all appeared to be highly erosional and benthic density and diversity were correspondingly low.

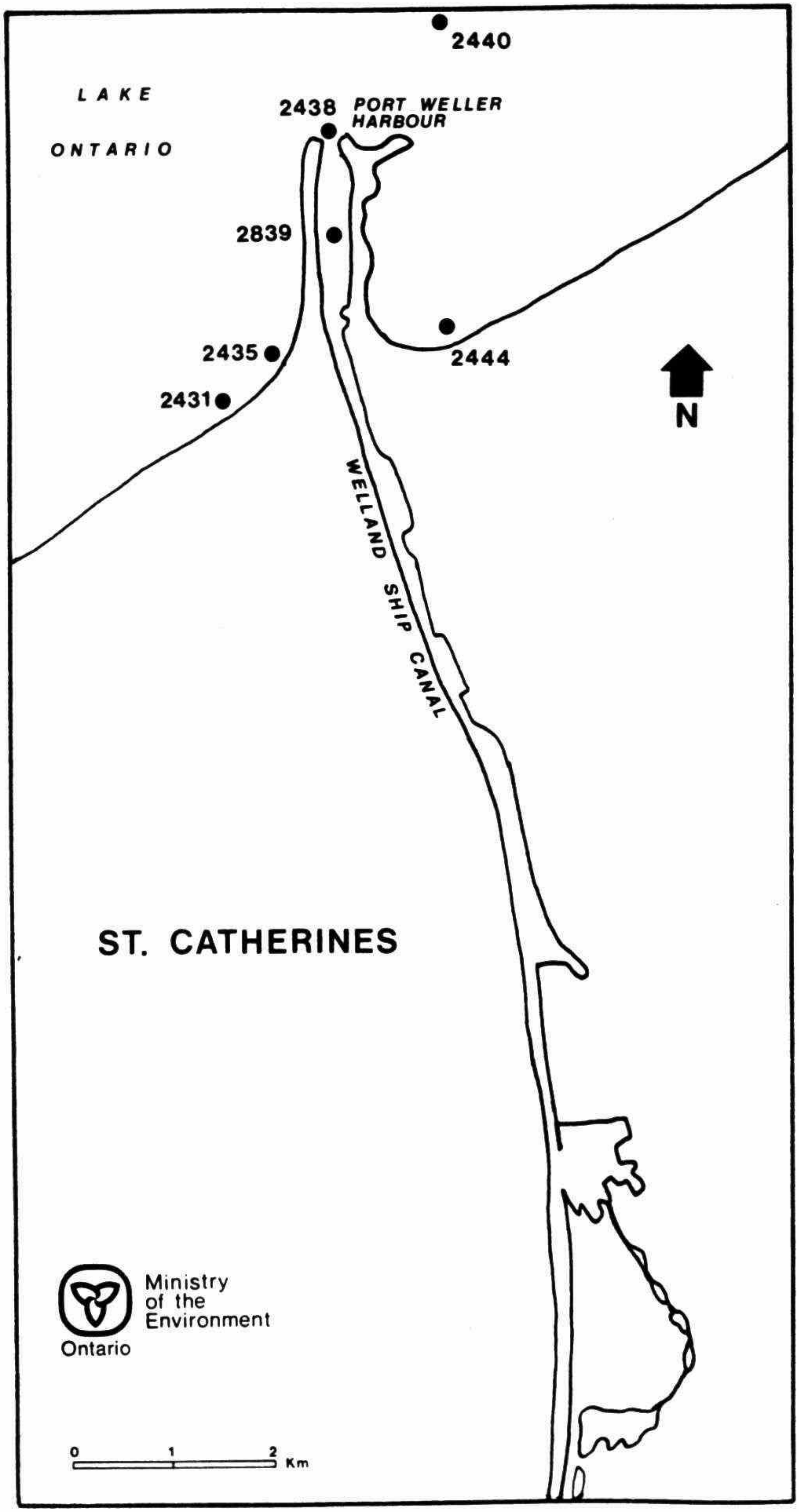

FIGURE 3.3: PORT WELLER HARBOUR, LOCATION OF SAMPLING STATIONS.

The most depauperate of these areas, Stations 2431 and 2444, yielded a community consisting mainly of small populations of chironomids and amphipods. The typical sediment infauna (oligochaetes) was almost entirely lacking, likely due to the highly erosional environment and low organic content.

The remaining two stations of this group had only minor oligochaete communities which were comprised mainly of those species with a known preference for sandy habitats.

Situated approximately 2 km northeast of the harbour entrance, Station 2440 had the most diverse fauna of any station within the study area. Sediments were a sand-silt mix and moderately high in organic content. Contaminant levels for most parameters were low except for PCBs which at 230 µg/g were nearly 5 times the MOE guidelines. A large and diverse benthic fauna occurred in this area, and though oligochaetes comprised the largest fraction, the most common species was Quistadrilus multisetosus, a species common in sandy areas.

The harbour (Station 2839) appeared to be a depositional area high in fine sediment content (silt and clay) and hence a high organic content. A typical soft sediment benthic community comprised of oligochaetes and chironomids was common here. The species present were those found in eutrophic areas, and consisted mainly of the Tubifex tubifex - Limnodrilus hoffmeisteri community often associated with organically enriched areas. Levels of contaminants were also higher than at any of the other stations, though these were generally only slightly above MOE guidelines. Therefore, toxic effects at this, and all other stations, could not be discerned.

3.1.4 Bay of Quinte

Of the ten stations located in the Bay of Quinte, 5 were located around the Waterfront of Trenton, while the remainder were located near Belleville (Figure 3.4).

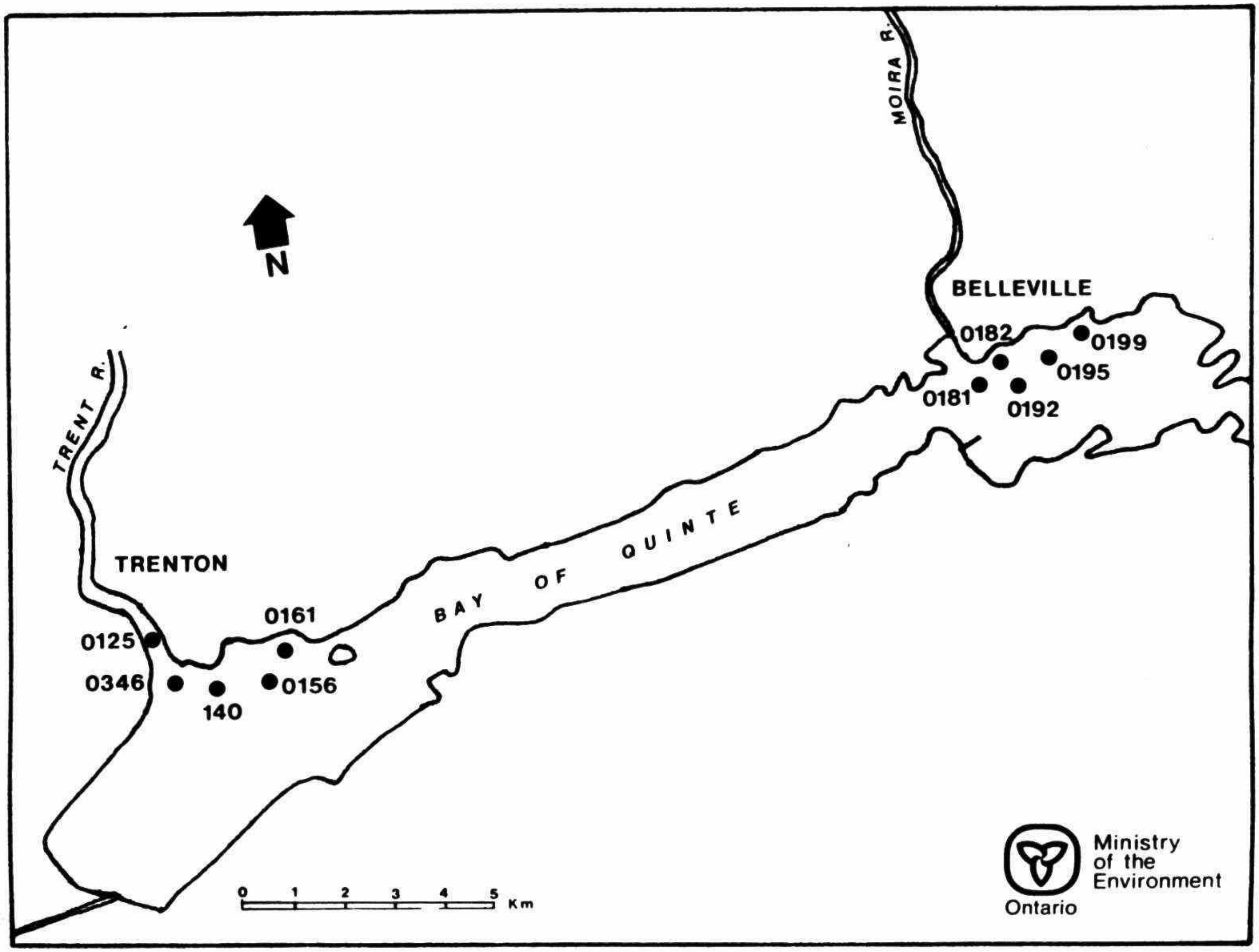

FIGURE 3.4: BAY OF QUINTE, LOCATION OF SAMPLING STATIONS.

Sediment quality data and benthic survey results indicate that organic content and sediment particle size were the major factors determining the composition of the benthic fauna along the Trenton waterfront. In the Trent River (Station 0125) substrate was mainly sand and hence low in organic content. Contaminant levels, with the exception of Cr and Zn were also low. Though faunal density was low as a result of the sandy sediments, the fauna was diverse and was comprised of both lotic and lentic species. The sediment infauna was noticeably sparse and comprised a very small portion of the fauna. The single largest fraction was the grazers (epibenthic) feeding on coarse organic detritus and macrophytes.

The remainder of the stations, located in the Bay of Quinte, were all in sandy areas varying from a low of 61% at Station 0156 to a high of 84% at Station 0161. Organic content and contaminant levels varied accordingly, though the latter generally remained below MOE guidelines. Though the fauna at all stations was typical of organically rich, littoral areas, some species commonly considered mesotrophic (<u>Potthastia</u>, <u>Orthocladius</u>) were present in low numbers.

Though sediment data were lacking for Station 0140, located off the sewage treatment plant, benthic data suggests that organic content was higher at this location. Density was the highest of any of the Bay of Quinte stations, especially of those species more common in fine sediments (<u>L</u>. <u>hoffmeisteri</u>, <u>Glyptotendipes</u>). The high density of <u>Gammarus</u> <u>fasciatus</u> additionally suggests the presence of organic detritus and/or macrophytes. Station 0161, also located near a sewage treatment plant did not yield a similar community and high sand content is the most likely reason.

The remaining five stations were located around Belleville (Figure 3.4). Three of these (0181, 0192 and 0195) were in predominantly silty areas very high in organic content. Contaminant levels were elevated at these stations as well, and though most exceeded MOE guidelines, they were not as high as areas around the Toronto Waterfront. Despite the high levels of

organic matter, the sediment infauna was greatly reduced from expected levels. Density of the entire fauna was much lower than would be anticipated and though levels of some contaminants were high (PCBs and solvent extractables) diversity was also high, indicating these had little effect.

Sediment data were lacking for Station 0182 though the reduced density and diversity suggest this was an area of hard substrates. Only epibenthic species were present in any significant numbers and the infauna was almost entirely lacking.

A similar situation existed at Station 0199, where sand and gravel together made up 88% of the sediment. Contaminant levels were predictably low as were levels of organic matter. The benthic infauna was noticeably reduced and again epibenthic species dominated.

In general, when the high levels of organic matter are taken into account, the benthic density was unusually low at Belleville though the diversity was high (all stations >2.20) and evenness of the taxa also high. All these factors, except for the organic content, suggest that eutrophic conditions and not polluted conditions prevail.

3.2 Lake Huron

3.2.1 Midland Bay

Station locations for Midland Bay are shown in Figure 3.5. In general, sediment conditions were variable and consisted of a sand - silt mixture which ranged from a high sand content (77%) at Station 513, to a low (10%) at Station 512. Organic content was consistently high, even at Station 513 (TOC = 32 mg/g), though contaminant levels in most cases were at or slightly above MOE guidelines. The exception was solvent extractables, which were consistently high. In broad terms, the harbour can be classified as eutrophic but does not appear to be polluted.

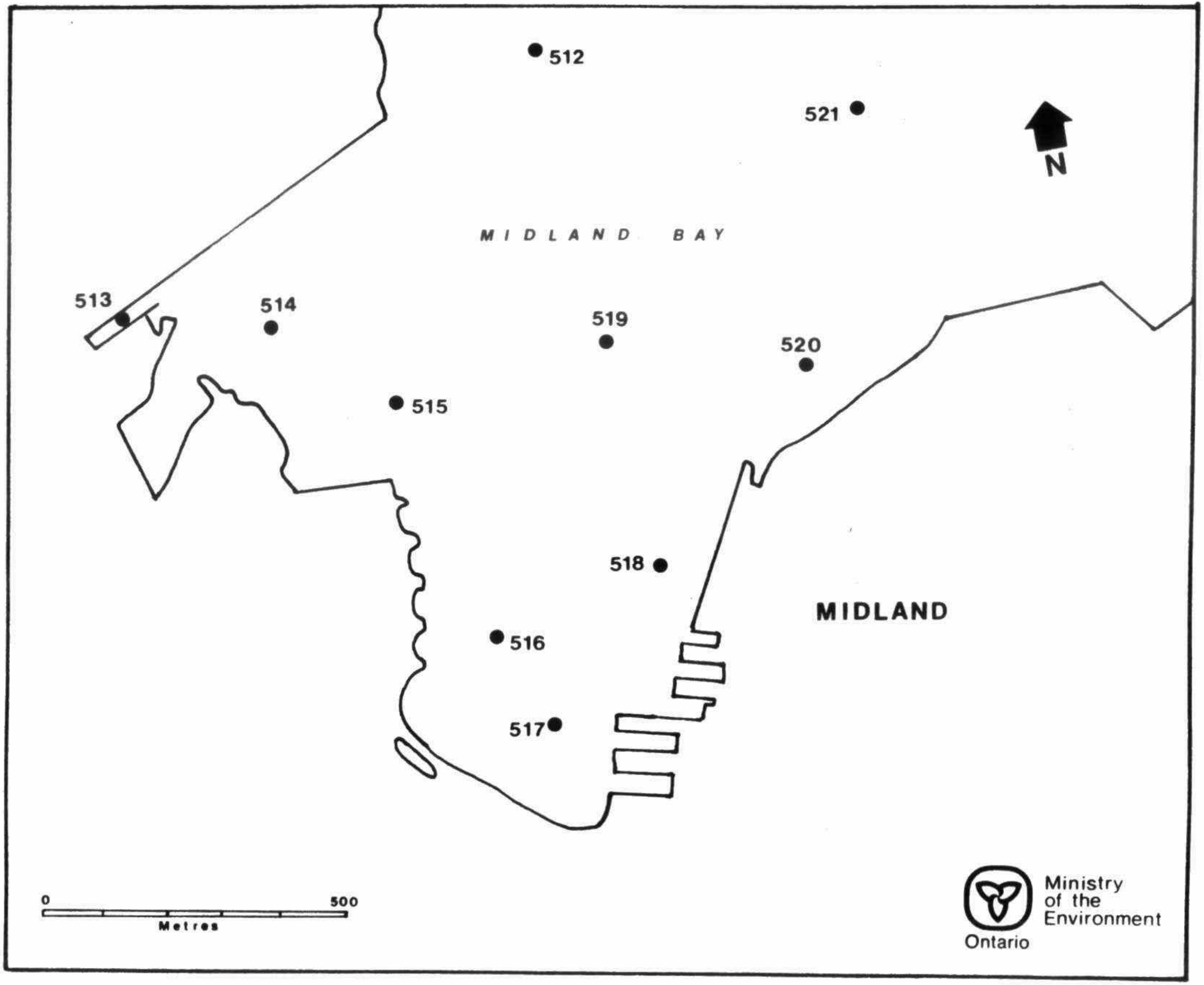

FIGURE 3.5: MIDLAND BAY, L. HURON, LOCATION OF SAMPLING STATIONS.

Though density fluctuated considerably among stations, the chironomid species (mainly Chironomus spp., Tanytarsus and Procladius) consistently comprised the major part of the benthic community at all stations. The sediment infauna (oligochaetes) comprised the second largest group, though these were usually species common in sandier substrates. The dominance of those species usually prevalent in organically polluted situations was lacking in the harbour.

Density ranged from a low of 492 $/m^2$ at Station 516, to a high of 7,016$/m^2$ at Station 520. While organic content and sediment grain size differed as well, species composition was more or less consistent. These differences however were not considered to be sufficiently great enough to effect significant changes in density, and other physical factors such as differences in microhabitat are the most likely factors.

None of the changes could be attributed to gross changes in any of the measured physical or chemical parameters. As such, little effect on the benthic communities in the harbour could be attributed to contaminant levels.

3.2.2 Penetang Harbour

The station locations for Penetang Harbour are shown in Figure 3.6. The benthic community in the Harbour appeared to be determined primarily by depth and sediment type. Shallow silty areas tended to be the most productive and the fauna in these areas (Stations 522, 523, 524, 525, 528, 529, and 530) was comprised mainly of sediment fine particle feeders, of which the chironomid species were the most common and diverse components. Oligochaetes played only a minor role in benthic composition, mainly as a result of this sediment type. While very productive, these areas bore no evidence of being organically polluted.

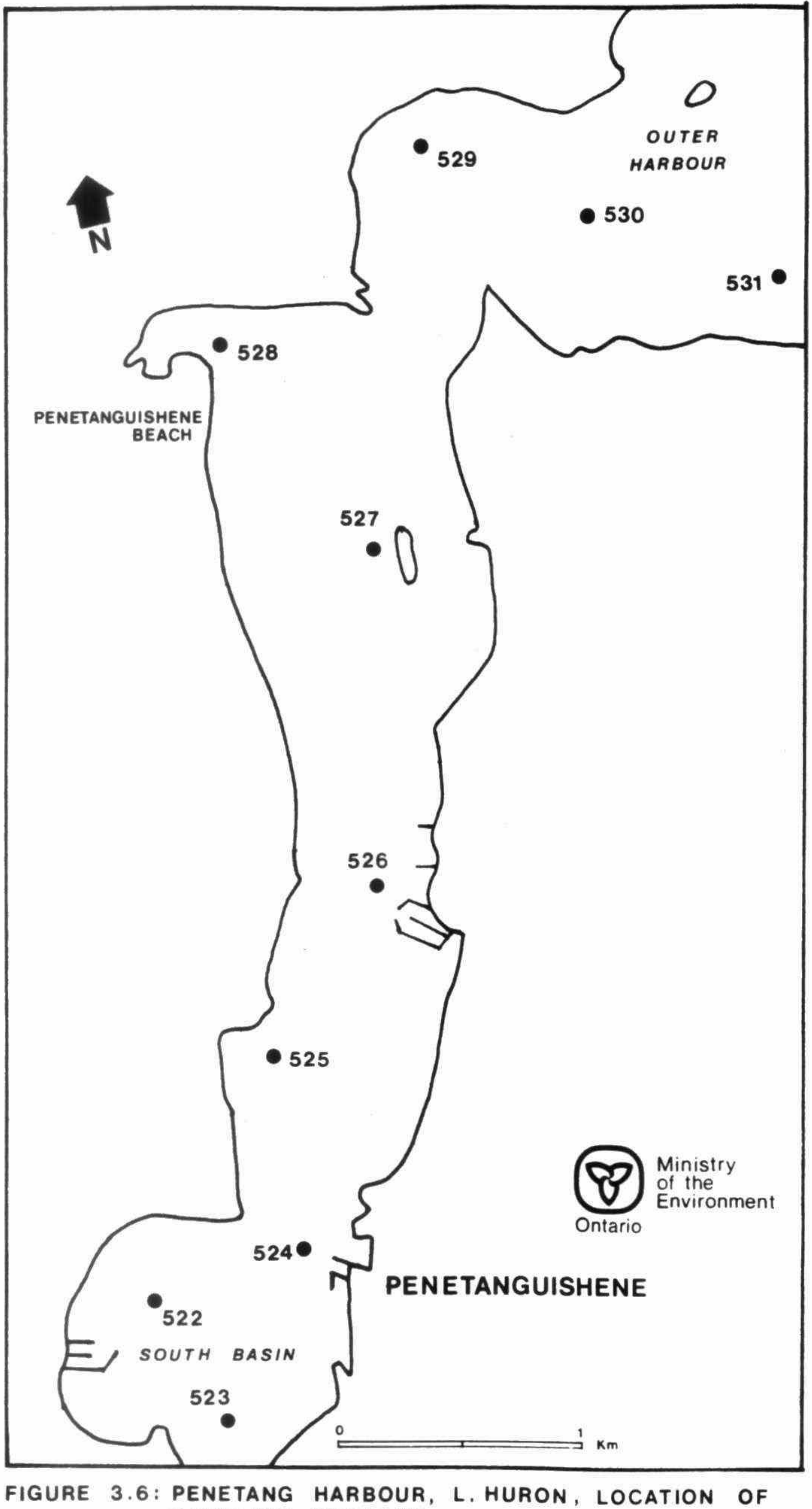

FIGURE 3.6: PENETANG HARBOUR, L. HURON, LOCATION OF SAMPLING STATIONS.

The most productive of these areas was Station 522, in the shallow south basin. Silt and organic content were the highest of any station in the harbour and not unexpectedly, benthic density and diversity were also high. Chironomid species comprised most of the fauna and one, Tanytarsus, made up over half of the total fauna. Chironomids as a whole were the most diverse group and this, coupled with the low density of oligochaetes, indicated that while eutrophic, the area was not heavily polluted.

The remainder of the stations in silty areas yielded similar results, though in most cases the organic content was much lower resulting in a corresponding decrease in density of organisms. Diversity remained high, with chironomids as the largest group at all stations except 524, where a diverse oligochaete community predominated.

Contaminant levels at the above stations were close to MOE guidelines for most parameters, but were slightly elevated at Station 522, which, as noted, also had the highest organic content. Solvent extractables were also high and most exceeded MOE guidelines. At Station 522 the levels were more than two times the allowable limit.

The deeper, sandy areas of the harbour (Stations 526, 527 and 531) were the least productive and sand content at these stations ranged from 85% to 89%. Two of these areas (Station 527 and 531) had accumulations of coarse detritus and at these a diverse and quite characteristic fauna appeared. Contaminant levels were very low at all three of the stations, consistent with the high sand content.

Density of organisms was lowest at Station 526 and the main component of the fauna was the oligochaete Quistadrilus multisetosus a species of sandy habitats. Density and diversity increased at both Station 527 and 531, and at the latter in particular, diversity was very high. Chironomids were the largest

and most diverse group though also of note were species of Trichoptera, Gammarus pseudolimnaeus and the gastropods, all of which, taken together, indicates the presence of coarse organic detritus.

Therefore, throughout the harbour changes in the benthic community structure are readily accounted for by changes in sediment texture and organic content. Even in areas of high organic content, diversity remained high and fell only when limited by the apparent availability of food. Contaminant levels were at or below guidelines in the majority of cases and did not have any discernable effect on the benthic community.

3.3 St. Marys River

Station locations for the St. Marys River are shown in Figure 3.7. Two major zones were apparent; upstream and downstream unimpacted areas, and an impacted midsection area, near stations 0049 and 0048.

These zones are similar to zones of impact determined in a much more extensive survey, carried out in 1985 (Beak, 1988). Multivariate statistical analysis of the Beak results provided similar groupings of stations as noted in this report.

Upstream areas (Stations 0078, 0051, and 0050) yielded diverse faunas in which coarse detrital feeders predominated, despite indications that these were areas of mainly sandy substrates. Densities of epibenthic grazers were high while densities of the fine sediment feeders, such as the oligochaetes, were very low. Sediment organic levels were correspondingly low, as were contaminant levels.

The impacted Stations (0049 and 0048) were located at, and downstream of, the Algoma Steel mill. Sediment contaminant levels were high and in some cases exceeded MOE guidelines by considerable amounts (solvent extractables were 8 times higher at Station 0049). Though high levels continued downstream at all

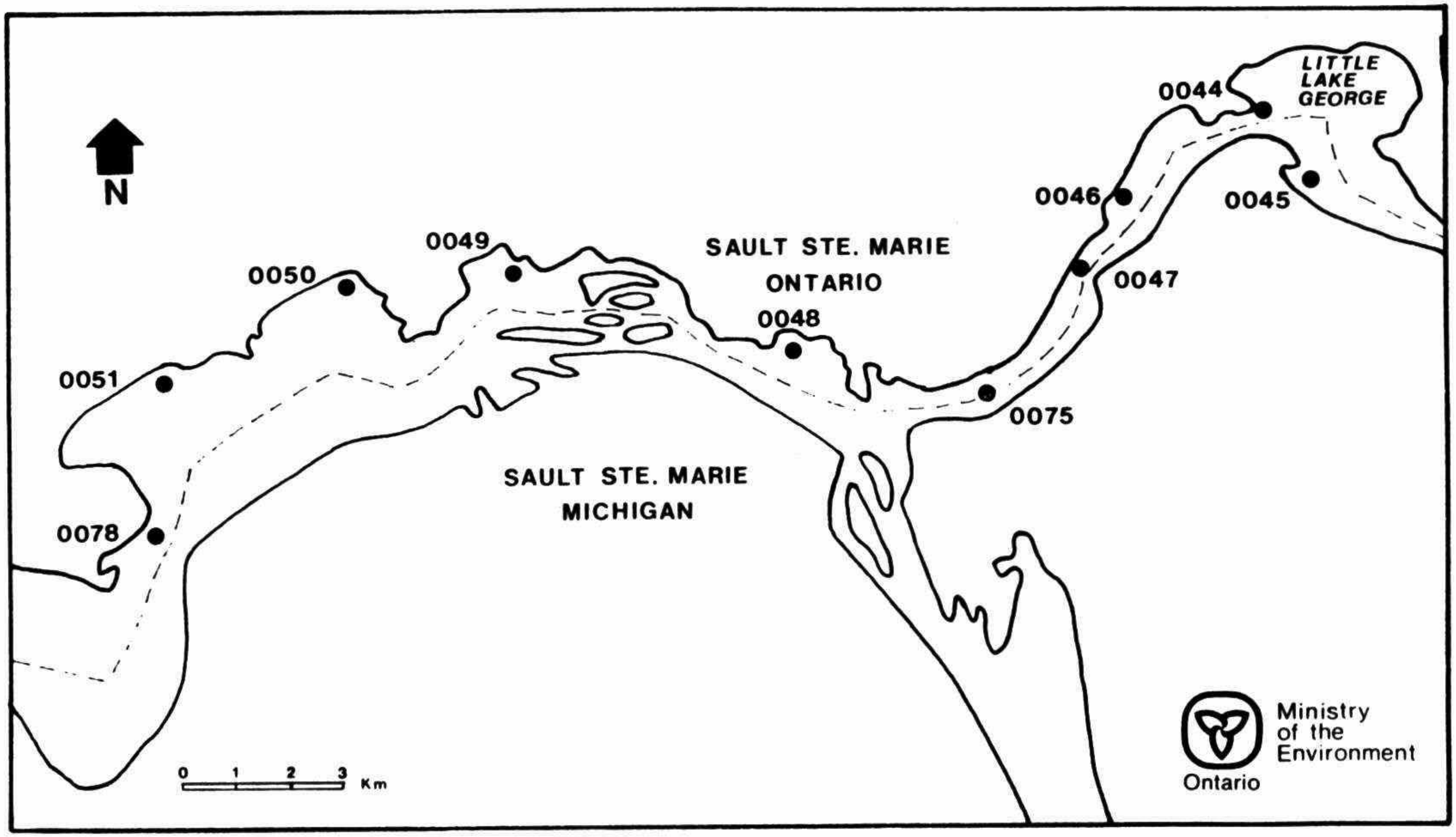

FIGURE 3.7: ST. MARYS RIVER, LOCATION OF SAMPLING STATIONS.

stations where silt content was high, there appeared to be little direct effect on the faunas at those stations though substrates were not directly comparable at all stations. Benthic density and diversity were seriously reduced at Stations 0049 and 0048 and despite high organic content and favourable sediment texture, at each station the fauna consisted of only a very reduced population of oligochaetes. Since the species commonly associated with organic pollution were also absent the effects of chemical contamination on the benthos are a strong possibility.

The benthic fauna increased in density and diversity with increasing distance downstream, though diversity did not recover to upstream levels. While contaminant levels were low in areas of sandy sediment (0044) they were nearly as high as at Stations 0049 and 0048 at the silty stations.

3.4 Detroit River

The sampling stations in the Detroit River are shown in Figure 3.8. A total of eight stations were located along the Michigan side or in the main channel, while two stations were located on the Ontario side.

In the main river channel, along the Michigan side of the river a steady reduction in both density and diversity of the benthic fauna was evident with increasing distance downstream. Furthest upstream, Station 0104 was closest to the normal condition for sandy areas in the main river though sediment contaminant levels were somewhat high for sandy substrates. Density and diversity were both low though sediment texture appeared to be the main controlling factor. Contaminant levels increased slightly at Station 0101, though the benthic community remained largely unchanged.

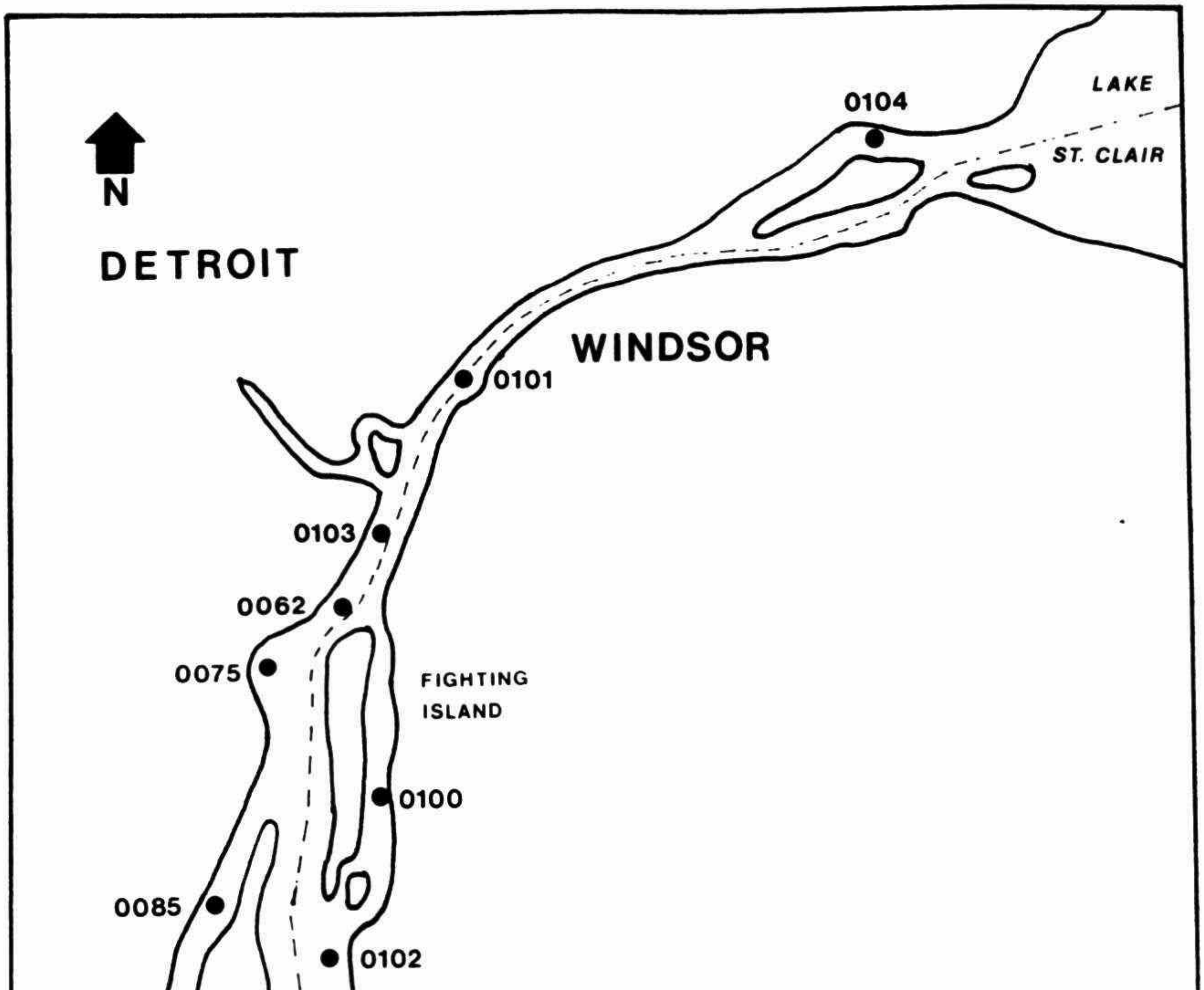

FIGURE 3.8: DETROIT RIVER, LOCATION OF SAMPLING STATIONS.

This relatively unpolluted zone was followed by an organically polluted zone in the upper area of the river (Stations 0103 and 0062). Levels of contaminants increased significantly and most exceeded MOE guidelines, some (e.g. solvent extractables) by 15 times (Station 0062). The benthos consisted primarily of oligochaetes in high densities. This increase was accompanied by an increase in the density of oligochaetes and particularly the pollution tolerant fauna. Overall, diversity decreased at these stations leaving only the Limnodrilus - Tubifex community.

This was followed in the middle and lower sections of the river by organically enriched and chemically contaminated areas (Stations 0085 and presumably 0075 and 0072 as well). The benthic community at these stations was severely reduced (mean of <100 individuals/ station) and comprised almost exclusively of oligochaetes. The reduced fauna appears to have resulted from chemical contamination.

A recovery of the fauna to one characteristic of organically polluted conditions was apparent at Station 0070, the furthest station downstream. Contaminant levels in the sediments were generally lower (though still high for sandy areas) and a moderately large oligochaete community was established here.

The two stations located on the Ontario side of the river at Fighting Island were markedly different from the other stations. Contaminant levels, in contrast to levels on the Michigan side, were relatively low and only a few slightly exceeded MOE guidelines. A very diverse benthic fauna existed at these locations (epibenthic grazers comprised the largest segments) and both of these stations appeared to be comprised of normal communities of lotic organisms.

3.5 **Niagara River**

Of the ten stations proposed for the Niagara River, samples were not obtained at two of these as a result of hard substrates. The eight stations sampled are shown in Figure 3.9.

The upstream station (0113-actually in Lake Erie) was typical of organically enriched areas, yielding high sediment organic values and elevated contaminant levels (most exceeded MOE guidelines though not by significant amounts). The benthic fauna was primarily oligochaetes, dominated by the pollution tolerant forms.

Hard substrates appear to have determined benthic composition at three of the stations in the river (0127, 0183, and 0154) since the fauna at these locations was restricted to epibenthic species (primarily filterers and algal grazers). Sediment burrowers of any kind were entirely absent.

Despite a moderately high sediment organic content at Station 0145, benthic density and diversity, especially of the sediment feeding fauna was low. Sediment contaminant levels were not unusually high, though solvent extractables and PCB's were considerably higher than the allowable guidelines. These contaminants alone were unlikely to have a major effect on the benthic community since only minor changes have been noted in other areas of similarly high, or higher levels.

The remainder of the stations were all located in mainly sandy areas (ranged from 74% to 89%). All three of these, 0158, 0155 and 0177, were located at or downstream of well-known toxic contaminant sources on the Niagara River. Despite the presence of contaminants, the benthic fauna at these stations were very similar and very diverse. Contaminant levels were generally low (below guidelines for most parameters). Epibenthic species dominated the benthic communities at all three stations and these were concentrated mainly in the filterer and grazer groups. The

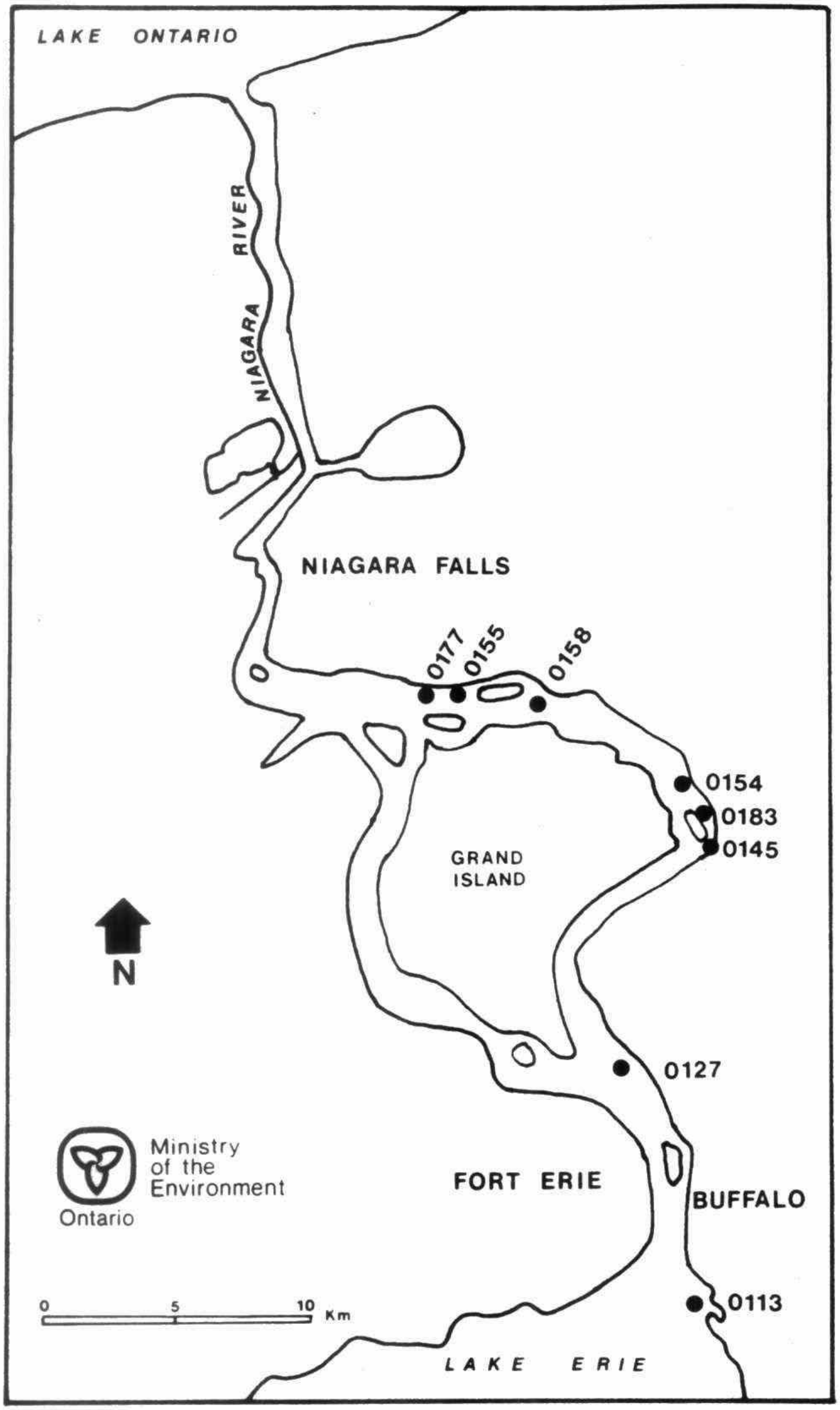

FIGURE 3.9: NIAGARA RIVER, LOCATION OF SAMPLING STATIONS.

sediment infauna, though very much reduced was not entirely absent. Similar results were obtained by Creese (1987) in a much more extensive survey of the Niagara River. Multivariate analysis of results yielded groupings similar to those noted in this report.

3.6(a) **St. Clair River**

The benthic community of the St. Clair River appeared to be primarily governed by the occurrence of organic matter in the sediment. Sediments at most stations (Figure 3.10) were primarily sand (ranged from 68% to 91%) and organic matter at all stations was low. As would be expected under such circumstances, contaminant levels were also low and only in a few instances did levels exceed MOE guidelines.

The benthic community throughout the river was dominated by epibenthic species, with filterers and grazers (on periphyton and seston) the most significant categories. Sediment fine particle feeders were generally reduced or absent. Chironomid species, amphipods, and snails were consistently the most important components of the fauna and diversity in all of these groups was high.

Two of the stations sampled (0024 and 0066) yielded depauperate faunas (mean densities < $100/m^2$). Substrate conditions (determined from sample residues) differed little between Station 0024 and the other stations. It is quite possible that the perchloroethylene spill that occurred earlier in 1985 in the vicinity of this station affected the benthic community (sample residues contained a black tarry substance that may have been part of this spill). Station 0066 gave little evidence of having been affected by the spill and rather, substrate appeared to be the main factor at this station. Sand and gravel made up 98% of the sediment at this station and thus little suitable substrate would have been available for most benthic species.

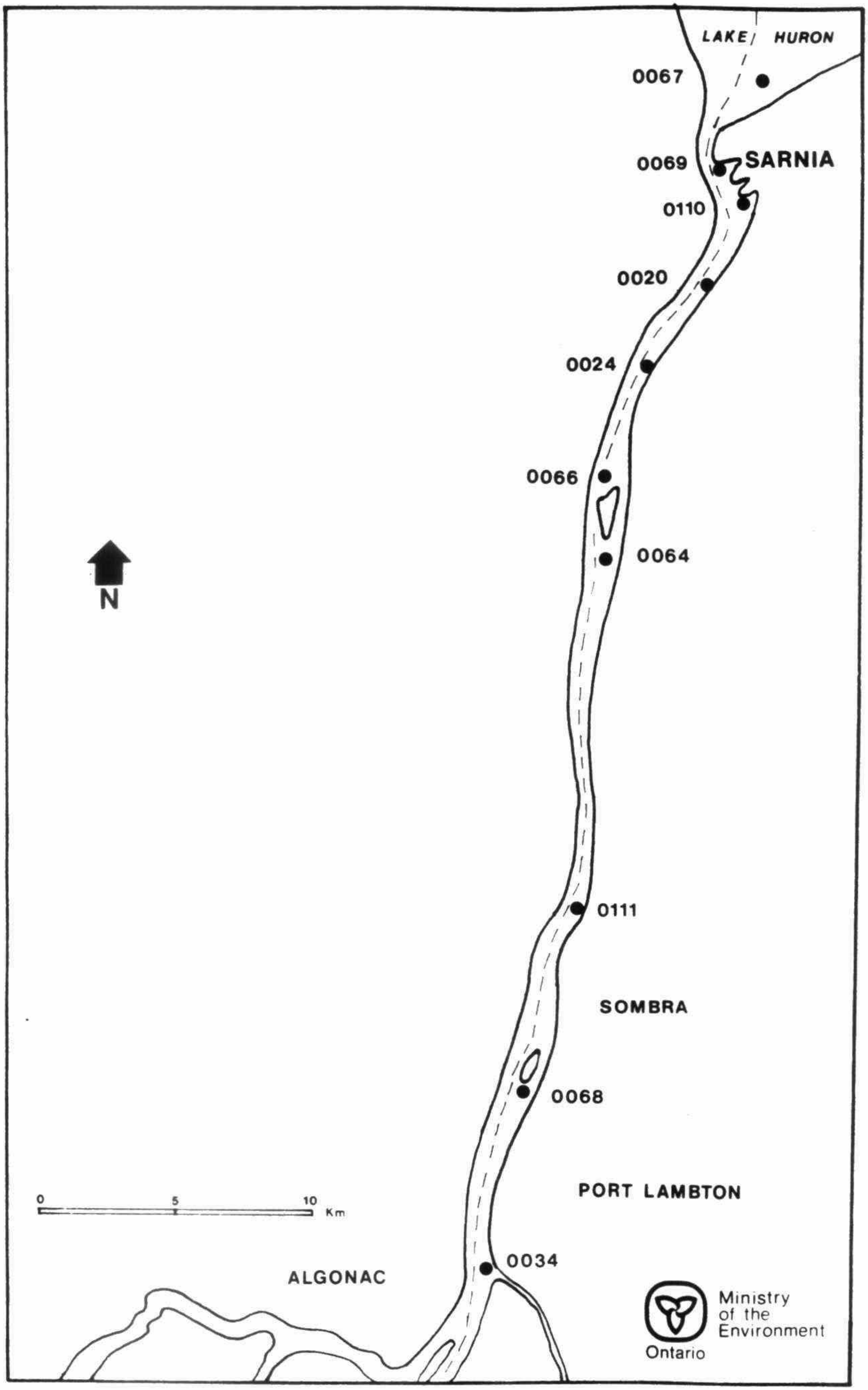

FIGURE 3.10: ST. CLAIR RIVER, LOCATION OF SAMPLING STATIONS.

Areas downstream compared very closely with upstream areas and a similar fauna was found at these stations. Density, though variable, appeared to fluctuate in relation to local substrate conditions and quite likely in relation to other, unmeasured, physical conditions. Contaminant levels in the sediment at all stations were so low that it was highly unlikely these played a part in the distribution and density of benthic species.

3.6(b) St. Clair River - Follow-up Survey

The St. Clair River survey of 1985 noted some localized effects on the benthic fauna in the region of the perchloroethylene spill. The follow-up survey, done in 1986, was performed to determine whether any long-term effects were evident. During the 1986 survey one additional parameter, current velocity, was also measured. This, not surprisingly, was found to be a major factor affecting the benthic fauna.

Though many of the stations did not correspond exactly between the two surveys, the general locations were usually the same. Sand substrates still predominated though the range was somewhat larger (52% to 91%). Contaminant levels showed little increase, being below MOE guidelines and similar to the 1985 results. Sediment organic content did not appear to have much effect on contaminant levels.

Three stations, 203, 038A, and 0068 were all in areas of moderately high current velocity and had similar faunas despite differences in substrate composition. These consisted primarily of filterers and grazers and thus were comparable with most of the stations in the 1985 survey. These areas exhibited little change from 1985 to 1986 except for an increase in density of organisms.

The other major determinant of benthic community composition was the presence of attached macrophytes, which according to MOE field data were most prevalent at Stations 0110, 218, 0064, and 0115. A similar fauna dominated at each of these stations, characterized by those species usually associated with macrophytes (*Gammarus fasciatus*, *Amnicola limosa* and *Endochironomus*). Filterers were less important at these stations though decreased current would have been the main factor. In general, at these, as well as the other stations, the oligochaete and *Pisidium* populations (fine sediment feeders) characteristic of accumulations of organic matter were all small relative to these other groups.

No effects similar to the reduced benthic communities at Station 0024 (1985) could be determined. The areas sampled all yielded diverse faunas, and density was very high at all stations. The assumption therefore is that any effects that may have been present in 1985 had dissipated by fall of 1986 (one year later).

4.0 DISCUSSION

The results of this study show that the composition of benthic communities varies considerably within and among geographical areas. Several factors, by themselves or in combination, appear to influence the composition of a community. Some of the more easily identifiable among these include substrate type, flow characteristics, water depth and the degree of organic enrichment.

According to traditional terminology used in characterizing areas based on benthic enumeration information, most of the stations sampled could be classed as either eutrophic or organically polluted. The communities in organically polluted areas (high organic matter content and low dissolved oxygen levels) characteristically showed high densities of only one or a few species that are known to tolerate such conditions. The composition of communities in eutrophic areas was represented by larger numbers of species at lower densities, more closely reflecting a community that is not experiencing any significant stress. It was also found that the typical riverine community was different from that found in most of the lentic (lake) or quiescent (no appreciable currents) areas sampled.

As indicated by the results, it would be extremely difficult to characterize an entire area, such as a harbour, as being eutrophic or organically polluted. In evaluating the data, it was found that these designations can change from station to station within a relatively small area depending on the type of sediment.

The best generalizations can be made in large study areas such as Toronto Harbour or Humber Bay where the variations in community composition were small enough to delineate zones of relatively similar communities.

In general it was relatively straightforward to relate the findings on community structure to one or more of the factors outlined above. It was somewhat more difficult to identify influences of chemical contaminants on the benthic community. In many instances, apparent effects of chemicals were noted in this study. However, confirmation would require further work of an experimental nature.

Defining cause-effect relationships between any of a mixture of chemical substances in sediment and the benthic community is a difficult and complex undertaking. In some cases this may not be feasible from field studies alone and even in a laboratory setting may prove impractical. The point that emerges from this is that great care must be taken when attempting to isolate specific chemically induced impacts due to contaminated sediments which normally contain a variety of chemical substances.

Many of the areas where the benthic population was reduced as a result of high organic matter content also had high levels of chemical contaminants. This was especially characteristic of areas that are directly influenced by point-source discharges such as the north shore of Toronto Harbour. Except for highly contaminated areas, contaminants in sediment did not appear to have any major impact on the organisms present, based on their high numbers. Minor effects could not readily be determined, since the organisms present were usually the most pollution-tolerant species. This was also demonstrated in another recent MOE study of the Niagara River which found that "a few highly contaminated sites showed flourishing invertebrate communities" (Creese, 1987). This however, does not preclude the likelihood that sensitive species may have been eliminated as a result of the contaminants.

Two explanations regarding the ability of organisms to survive in areas with high levels of contaminants in sediments have been discussed in an earlier report of the In-Place Pollutants Program (Persaud et al. 1987). One of these is that in areas with high organic enrichment, the organic matter binds the contaminants very strongly making them unavailable to the biota. Persaud et al. 1987 showed that organic content of the sediment was found to influence the levels of certain contaminants in the tissues of benthic organisms.

The other explanation, based on work carried out by Bryan (1979), is that organisms exposed to low concentrations of certain contaminants (especially metals) can develop a tolerance which in succeeding generations will become progressively greater to that contaminant.

For areas where historical data exist, this and other recent studies found improvements in the benthic communities over time concomitant with pollution control initiatives. In the present study, Toronto Harbour showed improvements over a 1970 study; a study of the Niagara River (Creese, 1987) found conditions had improved since those reported in 1968; a St. Lawrence study (Griffiths, 1988) found that in certain areas there was "considerable improvements over the past 19 years" and general improvement in the benthic community of the Detroit and St. Clair Rivers were noted from 1967-1983 (Thornley, 1985).

Results of a single benthic survey can provide a point-in-time assessment of the status of the benthic community in terms of community composition and biomass. Regularly repeated benthic surveys can be very useful in determining trends or changes in benthic communities over time. From the perspective of assessing the impacts of chemical contaminants on biota, benthic studies are used to greatest advantage in situations where a single substance or a specific discharge is being investigated. Assessments of mixtures of chemicals in sediments are problematic in relation to both field and laboratory studies. Benthic enumeration studies, when conducted with sufficient frequency and duration to account for natural variations in a system, have proven to be useful in monitoring changes resulting from abatement or clean-up once a good baseline has been established.

The ability of certain organisms to survive in areas with high levels of contaminants raises concerns related to the uptake of these contaminants and their potential for trophic transfer. It has been demonstrated that organisms do accumulate a variety of chemical substances especially in the vicinity of point-source discharges (Persaud et al. 1987). Evaluation of the significance of tissue levels, however, requires the establishment of acceptable tissue concentration values.

In addition to this concern, contaminated sediment management schemes will require information on what is considered an acceptable level in areas where the benthic communities are stressed. If management schemes require that the sediment be suitable for a particular benthic community, then appropriate studies will have to be carried out to determine what changes to the sediment must be effected to create a suitable environment for colonization by these species. In such instances, studies will have to determine the life history characteristics of the organism and examine the organisms' responses to a number of environmental conditions. This will require considerable time and effort, though there is no guarantee this will be any more effective than source control.

A more practical and scientifically defensible approach towards initiating immediate improvement in areas with stressed benthic communities is to reduce oxygen consuming wastes, nutrients and toxic chemicals by controlling effluent input. Several studies have shown that the benthic community is very resilient and once source controls are effected, the community can begin to recover (Bascom 1982; Rabeni et al. 1985; Sheehan 1984; Andrews 1984; Creese 1987, Beak 1988, Thornley 1985). Even in severely stressed areas, remedial action other than source reductions should not be based on field studies alone, but must be complemented by appropriate laboratory studies. These studies must establish the reasons for the stress and also examine the long-term sublethal effects of the sediments on the organisms.

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